Study forecasts disappearance of conifers due to climate change

December 21, 2015

Predicts widespread loss in the Southwest U.S. in this century

LOS ALAMOS, N.M., Dec. 21, 2015—A new study, led by Los Alamos National Laboratory, suggests that widespread loss of a major forest type, the pine-juniper woodlands of the Southwestern U.S., could be wiped out by the end of this century due to climate change, and that conifers throughout much of the Northern Hemisphere may be on a similar trajectory. New results, reported in a paper released today in the journal Nature Climate Change, suggests that global models may underestimate predictions of forest death.

“We have been uncertain about how big the risk of tree mortality was, but our ensemble of analyses — including experimental results, mechanistic regional models and more general global models— all show alarming rates of forest loss in coming decades,” said Los Alamos forest ecologist Nate McDowell, first author on the paper. “Given the recent climate talks in Paris and their focus on protecting forests, especially from deforestation, our results provide extra incentive to protect forests from the warming itself, which requires reducing emissions.”

2:33

Southwestern Pine Forests Likely To Disappear

The paper, authored by an international team, reveals consistent predictions of widespread mortality of needleleaf evergreen trees using state-of-the-art models evaluated against empirical data. Experimentally, the team found that dominant evergreens in the Southwest died when tree predawn water potential fell to levels that impaired the transport and stores of water and carbon. This predawn water potential, a measure of water stress, is the water status of the tree that results in part from soil water availability and atmospheric water demands on plant water use.

McDowell and his large team strove to provide the missing pieces of understanding tree death at three levels: plant, regional and global. The team rigorously developed and evaluated multiple process-based and empirical models against experimental results, and then compared these models to results from global vegetation models to examine independent simulations. They discovered that the global models simulated mortality throughout the Northern Hemisphere that was of similar magnitude, but much broader spatial scale, as the evaluated ecosystem models predicted for in the Southwest.

McDowell and colleagues demonstrated that predawn plant water potential is a key predictive element of tree mortality. The evaluated regional models accurately predicted the predawn water potential of evergreens and 91 percent of the predictions exceeded mortality thresholds this century due to rising temps.

Climate change's effects on trees

Trees, a precious carbon sink, become a carbon source when they die, so knowing how they interact with the climate and the carbon cycle is imperative to our climate's delicate balance.

The very mechanism that a tree uses to preserve its water stores during prolonged drought can be its undoing: the tree closes the stomata on its needles to prevent water loss, but this prevents the tree's food source, CO_2, from entering, halting photosynthesis. As the air becomes hotter and drier, subsequent pressure change pulls more water from the roots than can be supplied and the water tension in the plant's vascular system (xylem) can become so great that the straw-like columns no longer support water flow. The hydraulic system can collapse or the tree undergoes the starvation process, and it subsequently becomes defenseless against bark beetles and disease since it can no longer secrete the thick resin that protects it. As the tree decays after death, the carbon stored in its tissues is released into the atmosphere as carbon dioxide.

According to the authors, the atmospheric demand for water (vapor pressure deficit) is potentially the largest climate threat to survival because increasing temperatures are driving a chronic increase in evaporative demand *despite* increases in humidity. In other words, according to McDowell, trees may suffer in many places around the world, even in humid climates, due to global warming.

Validating dire conclusions

In a trifecta of expertise, McDowell and colleagues generated predictions using observations, experiments and models (empirical and process-based). The team used data from two of the world's largest drought studies, both based in New Mexico and developed by Los Alamos National Lab. At one site a large drought plot was installed that manipulates precipitation to test the impacts of drought, and the researchers then monitored the tree's reaction to these changes.

In a five-year study, the McDowell team's field experiments restricted precipitation by 50 percent to mimic drought conditions, resulting in 80 percent mortality of the mature pines. In parallel, the scientists developed cutting edge representations of tree mortality within their models and subsequently evaluated them against the drought-manipulation results as well as against an independent set of data from another site in Los Alamos where predawn water potential was monitored monthly for more than two decades. This resulted in the generation, and subsequent confidence in, state-of-the-art models of forest stress and mortality during drought.

Widespread loss of forests

The conclusion of widespread conifer loss in the Northern Hemisphere is consistent with widespread observations of accelerating forest mortality in North America. The authors note in this paper and in others that there are uncertainties and assumptions that could make the models too conservative or too liberal (killing too few, or too many trees, respectively). For example, wildfire was excluded from these models resulting in underestimates of mortality, but refugia, or islands of survival, are also missing from the models, resulting in overestimates of forest mortality.

"Resolving these uncertainties is a critical next step for the international community because we need forests now more than ever to absorb carbon dioxide, even as that carbon dioxide and associated warming is threatening their survival," McDowell said. "Based on the outcomes of the recent climate talks in Paris, we need to protect our forest to reduce the warming, but we simultaneously need to know how the warming can take out forests."

Rigorously validated, the experiments, observations, regional predictions and global simulations predict widespread conifer loss in coming decades under projected global warming. Knowing our conifers are so sensitive to warming provides even further incentive to reduce warming so we can simultaneously save forests and further slow warming. Such rapid and extensive forest losses are likely to have profound impacts on the carbon cycle, climate feedbacks and the health of ecosystems.

About the collaboration

Los Alamos coauthors that supported McDowell include Chonggang Xu, Turin Dickman, Sanna Sevanto, Jordan Muss and Park Williams (now at Columbia University). The collaboration included other coauthors from the University of New Mexico, University at Buffalo, INRA-Bordeaux Sciences, Duke University, U.S. Geological Survey, National Center for Atmospheric Research, University of Arizona, University of Delaware and Lawrence Berkeley National Laboratory.

The McDowell team's work has provided the foundation for much of this study.

Read more about the team's forest mortality developments:

- Drought-induced tree mortality accelerating in forests
- Multi-institutional project to study climate change's effect on tropical forests
- Los Alamos Science and Technology Magazine: 1663

Caption for image below: *Dying conifers in California's Sequoia National Park, home to the world's largest trees. (Credit: US Geological Survey)*